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New and noteworthy records of rodents (Mammalia, Rodentia, Cricetidae and Echimyidae) from Paraguay

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Abstract
Paraguay, situated in south-central South America, lies at the nexus of several major biomes, and exhibits high species richness for a relatively small country. Nevertheless, that faunal diversity is poorly known, and new species for the country continue to come to light. This paper reports on 3 species of rodents, 1 new for the country and 2 known previously in Paraguay from 1 specimen. We emphasize the need for more and better training of new field and museum biologists, as well as for directors of permitting agencies and protected areas.

Keywords
Delomys; Interior Atlantic Forest; *Juliomys*; *Kannabateomys*; Mbaracayú.

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Introduction

Paraguay, a landlocked country in south-central South America, sits at the confluence of several major South American biomes—Pantanal, Interior Atlantic Forest, Cerrado, and Humid and Dry Chaco (Olson et al. 2001). Lying between ca 19 and 28 ° S, it is traversed by the Tropic of Capricorn, and thus includes both tropical and subtropical regions. Falling between ca 54 and 63° W longitude, the country includes a southeast to northwest annual precipitation gradient of from 1800–400 mm. Not surprisingly the country harbors a high diversity of animal species, including mammals, with 181 native mammal species currently recognized (de la Sancha et al. 2017).

The number of recognized mammal species in Paraguay has risen markedly during the past 2 decades. Myers et al. (2002) listed 156 species, but increased collecting activity and scrutiny of previously collected specimens has revealed that several species' distributions thought to terminate in Brazil or Argentina, actually extend into Paraguay. Most of these new records for the country were didelphid marsupials (Voss et al. 2009, de la Sancha and D'Elía 2015), bats (Stevens et al. 2010, Owen et al. 2014), and rodents (D'Elía et al. 2008, de la Sancha et al. 2009), but some have also been larger species (Smith et al. 2011, 2013).

Of the 181 Paraguayan mammal species, 34 (representing 20 genera) pertain to the subfamily Sigmodontinae (family Cricetidae), a widespread and species-rich radiation in the Neotropics. Another 22 species, representing 9 families, bring the total to 56 recognized Paraguayan rodent species. Among these, at least 2 species are

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recorded in Paraguay from only 1 specimen. This report adds 1 new genus and species to the list of Paraguayan rodents, and provides new specimen localities for 2 which are known from only 1 specimen.

Methods

A long-term project on small mammal and *Hantavirus* ecology and evolution by personnel from Texas Tech University and the University of Tennessee Health Sciences Center, Memphis, has involved multiyear sampling of small mammals in the Reserva Natural del Bosque Mbaracayú (RNBM), Canindeyú Department, northeastern Paraguay. The area of the reserve is approximately 65,000 ha. Most of the vegetation, including the area where we sampled, is mature Upper Paraná Atlantic Forest (UPAF), some of which was selectively logged in the past, but undisturbed for at least the last 35 years. Our sampling has included both collecting and mark-recapture sampling, and has been conducted in various areas within and around the reserve during the years 1995–96, 2001–08, and 2014–17. Our database includes approximately 7,780 capture records from the RNBM, and has revealed a high diversity both of sigmodontine rodents and small didelphid marsupials (Barreto Cáceres 2017).

Most recently (2015–17), 6 sampling grids were established to monitor small mammal population levels and community composition (and *Hantavirus* seroprevalence) on a seasonal basis, through 2 years. Each grid consisted of 12 × 12 = 144 trap stations, 10 m apart, and thus sampled approximately 1.44 ha of the forest. Each station included 2 standard Sherman™ traps (7.6 × 8.9 × 22.9 cm; Sherman Trap Company, Tallahassee, FL) placed about 1 m apart on the ground at the station point, and another trap placed 2–3 m above the ground on branches or in vines as near as possible to the station point as vegetation permitted. Each grid was run for 5 nights during 6 sampling sessions, for a total of 77,760 trap-nights. In addition, 16 pitfall traps were situated uniformly in a 4 × 4 = 16 pattern on 3 of the grids. These traps were opened for 3 consecutive nights in August, September, October, and December 2016, and January 2017 (16 traps, 3 grids, 3 nights, 5 sessions, for a total of 720 pitfall trap-nights).

In a separate research program, Para La Tierra (a research-oriented non-governmental organization created in 2010 and based in Paraguay), has involved approximately 310 volunteers, interns, visiting scientists and staff in developing a zoological collection including both invertebrates and vertebrates. Most of their collecting has been in departamentos San Pedro (adjacent to Canindeyú) and Ñeembucú (southwestern Paraguay), and they also collect opportunistically when animals are encountered elsewhere.

Specimens reported in this article were collected under Permisos de Colecta Científica N°. 011/2014, 132/2015, 269/2016, and 141/2017. Animals which were collected alive were euthanized following the Animal Care and Use Committee guidelines of the American Society of Mammalogists for the use of wild mammals in research and education (Sikes et al. 2011, 2016). All animal procedures were approved (Approval No. 14024-03) by the Texas Tech University Institutional Animal Care and Use Committee (IACUC), which follows the 8th Edition of the Guide for the Care and Use of Laboratory Animals (Guide), NRC 2011. The study did not involve endangered or protected species. Specimens which are deposited in the collection of R. Owen are housed there temporarily by request of the Museo Nacional de Historia Natural del Paraguay, where they will be permanently deposited when the museum has the resources to house them.

One new sigmodontine species is reported here for Paraguay, and new specimens and localities are reported from 2 additional rodent species that were previously known from only 1 specimen from Paraguay (Fig. 1). For each of the 3 species, collecting data are provided, as well as a description of the new specimens, followed by information on reproductive status, habitat and associations with other species. Nomenclature follows Patton et al. (2015) and authors therein.

Results

New records.

***Delomys dorsalis* (Hensel, 1872).** Paraguay, Canindeyú Department, Reserva Natural del Bosque Mbaracayú (23.9964° S, 055.3671° W), collected by R. Owen and I. Mora, 6 October 2003, 1 adult female, R. Owen collection, field number TK 121143. Paraguay, Canindeyú Department, Reserva Natural del Bosque Mbaracayú (24.1424° S, 055.3454° W), collected by R. Owen, H. Sánchez, and C. Jonsson, 27 August 2014, 1 adult male, R. Owen collection, field number TK 184693.

***Juliomys* cf. *pictipes* (Osgood, 1933).** Paraguay, Canindeyú Department, Reserva Natural del Bosque Mbaracayú (24.1410° S, 055.3663° W), collected by R. Owen and H. Sánchez, 15 July 2016, one adult male, R. Owen collection, field number 170166. Paraguay, Canindeyú Department, Reserva Natural del Bosque Mbaracayú (24.1414° S, 055.3659° W), collected by R. Owen, H. Sánchez and C. Jonsson, 15 February 2017, 1 adult female, R. Owen collection, field number TK 186360.

***Kannabateomys amblyonyx* (Wagner, 1845).** Paraguay, Itapúa Department, 7.9 km southeast of Alto Vera (26.8111° S, 055.7201° W), collected by K. Atkinson and L. McMahon, 22 October 2017, 1 subadult male, Zoological Collections of Para La Tierra, CZPLT 486.

Comments and identification. The adult female *Delomys dorsalis* (TK 121143), with vagina closed, was captured in a Sherman trap placed on the ground. The locality is in a transitional area between bamboo forest (*Guadua angustifolia*) and primary semideciduous forest of medium height, along the edges of Arroyo Karapá

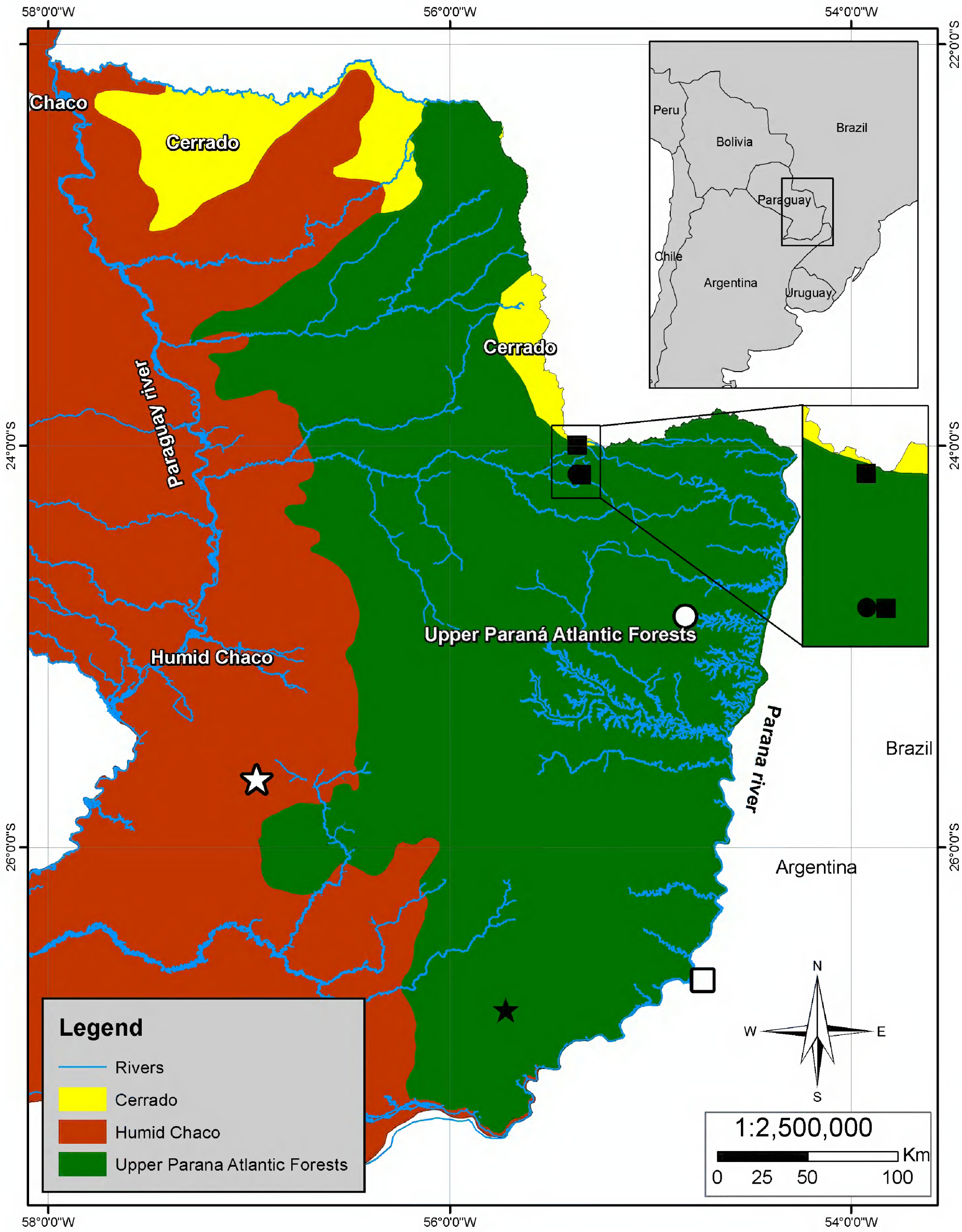

Figure 1. Map of eastern Paraguay showing major biomes and localities of specimens reported in this paper. The map also indicates nearest previously reported localities for the same species. Localities are: circles, *Juliomys pictipes*, TK 170166, TK 186360 (new localities, closed circle) and FACEN-CZ 014 (previous locality [de la Sancha et al. 2009], open circle); squares, *Delomys dorsalis*, TK 141143, TK 184693 (new localities, closed squares) and FMNH 26818 (previous locality [Gonçalves and Oliveira 2014], open square); stars, *Kannabateomys amblyonyx*, CZPLT 486 (new locality, closed star) and BMNH 1903.4.7.20 (previous locality [Thomas 1903], open star).

in the upper reaches of an escarpment known as the Cordillera Mbaracayú. The specimen was prepared as a fluid-preserved body with skull extracted and cleaned, and was initially identified and cataloged as *Hylaeamys megacephalus*, which the species strongly resembles externally. Later examination of the cleaned skull and re-examination of the body revealed that it represented a species not yet recorded from Paraguay, which was

Figure 2. Dorsal and ventral views of the crania of 2 *Delomys dorsalis* and 1 *Hylaeamys megacephalus*. Left, TK 121143; center, TK 184693 (both *D. dorsalis*); right, TK 130631 (*H. megacephalus*). See Table 1 for measurements of the *D. dorsalis* skulls.

subsequently determined to be *Delomys dorsalis*.

The adult male *D. dorsalis* (TK 184693), with scrotal testes (15 × 7 mm) was collected in a Sherman trap placed on the ground at a locality ca 16 km south of the first specimen. This was in a trapping transect in an area of the RNBM characterized as bamboo understory, which typically is a high forest with a dense understory predominantly of *Merostachys clausseni* bamboo, 2–3 m in height (Naidoo and Hill, 2006). The animal was prepared as a standard skin and skull specimen.

These 2 specimens are clearly distinguished from externally similar species (principally *Hylaeamys megacephalus*) by a number of skull characteristics, the most obvious being the much shorter palatine foramina found in *Hylaeamys*, and the distinctly longer rostral tube in *Delomys* (Fig. 2). The interorbital region in *H. megacephalus* is generally ridged, but is smooth in these 2 *Delomys* specimens. Externally, the mystacial vibrissae of the *Delomys* extend beyond the bases of the ears, whereas in *Hylaeamys* the vibrissae do not reach the ears. The claw of hind-foot digit I in *Delomys* extends well beyond the first interphalangeal joint in digit II, but barely reaches it in *Hylaeamys*. Ventral pelage of our dry specimen of *Delomys* is markedly dark gray-based and white-tipped, whereas that of *H. megacephalus* from the same locality shows less contrast between base and tip. The darker mid-dorsal pelage often observed in *Delomys* is minimally but clearly visible in our dry specimen (Fig. 3). Based on both geographic proximity and external morphologic characters, we identify these specimens as *D. dorsalis*. The tail of the dry skin specimen is only weakly bicolored, and the dorsal pelage is generally dark-cinnamon, with a moderately well-defined darker mid-dorsal stripe. The nearest collecting locality for another species of *Delomys*

Figure 3. Dorsal and ventral views of study skins of *Delomys dorsalis* and *Hylaeamys megacephalus*. Left, TK 121143, *Delomys dorsalis*; right, TK 130621, *Hylaeamys megacephalus*. Note the faint dark mid-dorsal band on the *Delomys*.

(*D. sublineatus*) is approximately 690 km distant, near the Atlantic coast in Paraná state, Brazil (Gonçalves and Oliveira 2014). External and cranial measurements of these 2 specimens are provided in Table 1.

Other species collected in the same trap line as TK 121143 were *Akodon montensis, Oligoryzomys nigripes*, and *Oligoryzomys* sp. Species collected in the same sampling line as TK 184693 were *Akodon montensis, Hylaeamys megacephalus, Oligoryzomys nigripes*, and *Sooretamys angouya*.

These new specimens represent a distribution extension of about 285 km north-northwest from the nearest previously known locality (Caraguatay, Misiones Province, Argentina—the only record from Argentina) (Gonçalves and Oliveira 2014). More importantly, these are the first localities recorded from west of the Paraná River, and are the first reported from the Paraguay River watershed.

The adult male *Juliomys* (TK 170166), with scrotal testes was collected in the dry season, and the adult female with vagina closed was collected in the wet season. Both of these animals were captured in Sherman traps set 2–3 m above the ground, on branches or lianas. The localities of these 2 captures were approximately 60 m apart. These records are approximately 115 km northwest from the locality of the only other Paraguayan specimen, and also are the first records of the species in the Paraguay River watershed.

These animals were easily distinguished from other possible species (principally *Oligoryzomys nigripes*) by their reddish rumps and rostra, tails distinctly bicolored and shorter than those of *Oligoryzomys*, and especially the reddish-orange coloration of the dorsal pelage, and pronounced white ungual tufts, of their hind feet (Fig. 4). Based on geographical proximity we tentatively identify these specimens as *J. pictipes*. The nearest locality recorded for another species of *Juliomys* (*J. ossitenuis*) is about 540 km away, in Paraná state, Brazil (Christoff et al. 2016). Nevertheless, our 2 specimens appear to more closely concur with the description of *J. ossitenuis* (Pavan and Leite 2011), and direct comparisons with other specimens are warranted. Although we report these specimens as a noteworthy locality for *J. pictipes*, re-indentification as *J. ossitenuis* would add yet another species to the list of Paraguayan mammals. The 2 individuals reported here were prepared as standard skin and skull preparations. External and cranial measurements of these 2 specimens are provided in Table 1. Measurements of the other Paraguayan specimen (FACEN-CZ 014) were listed in de la Sancha et al. (2009). We were unable to compare the prepared skins of our specimens with that of the other Paraguayan specimen, as that skin cannot be located. Photographs of the skulls of the 3 Paraguayan specimens are shown in Fig. 5.

Both of these individuals were collected on the same

Table 1. External and cranial measurements from 5 specimens of 3 species reported in this paper. External measurements in millimeters, and weight in grams, taken from specimen tag and/or collector's notes. Cranial measurements in millimeters taken following Tribe (1996) by R. Owen, except for CZPLT 486, taken by L. McMahon.

Characters	*Juliomys* cf. *pictipes*		*Delomys dorsalis*		*Kannabateomys amblyonyx*
	TK 170166	TK 186360	TK 121143	TK 184693	CZPLT 486
Total	191	190	255	262	328
Tail	97	93	126	132	194
Hind foot	20	18	30	28	40
Ear	15	14	20	21	18
Weight	25	19	42	51	97
ONL	24.41	25.64	32.64	32.84	44.35
PL	10.93	11.47	14.47	14.25	18.49
PPL	8.81	9.34	11.61	11.98	NA
MRC	3.50	3.91	4.57	4.40	8.29
M1B	1.03	1.16	1.33	1.35	4.53
PBL	3.68	3.67	5.18	4.79	9.69
TFL	7.59	7.12	10.05	9.65	12.88
DL	6.01	6.20	8.65	8.69	9.06
IFL	4.00	4.88	6.09	6.49	8.25
IFB	1.79	2.00	2.30	2.55	2.34
PB1	2.01	2.23	3.04	3.05	1.42
PB3	2.35	2.85	3.37	3.47	1.89
MFB	1.44	1.66	2.25	2.48	NA
BIT	1.71	1.77	2.17	1.73	2.65
BW	3.42	3.76	4.63	3.65	7.53
BL	5.34	5.66	4.52	4.04	NA
BCB	11.25	11.82	12.43	13.34	19.25
SH	7.41	7.88	8.48	8.70	13.77
RH	4.64	5.09	5.67	5.57	9.00
RB	4.26	4.64	5.80	5.78	6.77
RL	7.80	7.85	12.15	12.12	13.25
NL	8.78	8.92	13.66	13.14	12.39
ZPL	1.83	2.06	2.86	2.75	6.60
IOB	4.12	4.09	5.17	4.97	11.85
ZB	13.05	13.77	15.37	15.54	22.08
GLM	12.95	12.58	14.62	14.95	23.88
MMR	4.08	3.70	4.86	4.74	9.49
DR	2.42	2.49	2.76	3.21	7.01

sampling grid, which is characterized as dense forest with abundant lianas, mostly of family Bignoniaceae, associated with large trees. The ground slopes northeasterly with a maximum slope of 6°. Mature trees reach an average height of 15 m. The upper canopy reaches 24 m in height and several of the tree species are deciduous. *Astronium fraxinifolium* is the most characteristic species, followed by *Ocotea puberula*, *Peltophorum dubium, Inga affinis*, and *Parapiptadenia rigida*. The lower arboreal stratum is characterized by *Guarea kunthiana*, *O. puberula*, and *Chrysophyllum gonocarpum*. Other species that appear less frequently are *Nectandra megapotamica, Cabralea canjerana, Cariniana estrellensis*, and *Rheedia brasiliensis*. On average these species reach 8 m and grow associated with various species of lianas. The most frequent species of the shrub layer, which measures an average of 3.1 m in height, are *Guarea kunthiana, Sorocea bonplandii*, and *Rheedia brasiliensis*. It is common to find regenerations of *Nectandra megapotamica* of no more than 2 m and dense groups of *Piper hispidum* sometimes associated with *P. amalago*. In the clearings left by the fallen trees there is a rapid colonization of lianas that almost completely cover herbs and shrubs.

Other small mammals captured on the same sampling grid during 1 or both of the same sampling sessions were *Gracilinanus agilis, Monodelphis kunsi*, and *Marmosa paraguayana* (family Didelphidae), and *Akodon montensis, Cerradomys maracajuensis, Hylaeamys megacephalus, Oligoryzomys mattogrossae, O. nigripes,* and *Rhipidomys macrurus* (subfamily Sigmodontinae). *Calomys callosus*, *Euryoryzomys russatus, Oligoryzomys* cf. *flavescens,* and *Sooretamys angouya* (Sigmodontinae) were also collected on this grid, at other times.

The subadult male *Kannabateomys amblyonyx* (CZPLT 486) was found dead on the side of the road by a bridge over the Arroyo Palmito, in southern Paraguay, in an area of degraded Interior Atlantic Forest. The bridge spans a stream leading to San Benito, a shallow lake approximately 650 m away. The area is surrounded by a mosaic of small-holder farms, natural grassland, and a pine plantation, and a narrow corridor of degraded forest to the west incorporating mostly secondary growth flora

Figure 4. Dorsal view of hind feet of 2 *Juliomys pictipes*. Left, TK 170166; right, TK 186360. Note reddish-orange coloration of dorsal hairs, and white ungual tufts, characteristic of this species.

and degraded gallery forest to the south, both containing bamboo thickets.

This species is known in Paraguay from 1 other specimen, collected in 1902 in Sapucai, Paraguarí Department (Thomas 1903), approximately 175 km northwest of our locality. A third specimen, reported to be from Capitán Meza, Itapúa Department, collected by Adolfo Neuntenfel (date not specified, but probably 1938 or 1939), is housed in the Museo Argentino de Ciencias Naturales «Bernardino Rivadavia» in Buenos Aires. Approximately 170 specimens from the same collector are listed from the same locality, and it is unclear whether they were collected there or collected in nearby localities, including northern Argentina, and shipped from Capitán Meza. Thus, we cannot confidently consider this to be a Paraguayan record for *K. amblyonyx*. Additionally, a reliable sight record was reported from Estancia Nueva Gambach (26.6379° S, 055.6643° W) on the southern tip of San Rafael National Park on 12 December 2011 (P. Smith, pers. comm.).

The species is easily distinguished from all other rodents in Paraguay by its size (Table 1), generally dull buffy yellowish pelage, distinctly pale with grey and black flecks around the mouth, chin and chest, and the conformation of its hind foot, especially the toes (Fig. 6). The new specimen reported here is the first confirmed specimen from Paraguay in over a century. Endemic to the Atlantic Forest of Paraguay, Brazil and Argentina, the southern bamboo rat is a bamboo specialist (Stallings et al. 1994), with an exclusive diet of shoots and leaves of bamboo, as well as using bamboo for arboreal travel (Kierulff et al. 1991, Olmos et al. 2009). They are known to live inside thickets of bamboo near to waterways, including in planted or naturally occurring bamboo patches in close proximity to agriculture (Emmons et al. 2015).

Thomas (1903) described *Kannabateomys amblyonyx pallidior* based on the specimen from Sapucay, listing it as a paler subspecies of *K. amblyonyx* previously described from São Paulo, Brazil. The new specimen concurs with several of the features he described, including a general pelage of dull buffy yellowish, long and soft fur, and a pale, nearly white, venter. The head is darker than the body with less buffy yellowish coloring and more gray and black flecks; and around the mouth, chin, and chest it is paler to white. The vibrissae are long, dark and dense. The base of the tail is thickened and similar in color to the dorsal aspect of the body. From the mid-point to the tip of the tail the pelage becomes paler and white. The tail is furred to the tip, and the terminus has brown and black flecks, concurring with the description of the species by Emmons et al. (2015), rather than the white tip described for *K. a. pallidior* by Thomas (1903). The ventral surface of the limbs is pale yellow to white, with paler fur on

Figure 5. Dorsal and ventral views of the crania of three *Juliomys pictipes* from Paraguay. Left, FACEN-CZ 014; center, TK 170166; right, TK 186360. See Table 1 for measurements of the 2 skulls.

the tips of the digits of all 4 feet. This is consistent with the description for both *K. amblyonyx* and its subspecies *K. a. pallidior*. However, caution should be used, as the descriptions were both based on adult animals, and our specimen is a subadult. Further geographical study is required to determine the validity of the subspecies (Emmons et al. 2015).

Discussion

Numerous authors have noted that the mammalian fauna of Paraguay is poorly known (e.g. Myers 2002, López-González et al. 2014, de la Sancha et al. 2017), and new species continue to be added to the known mammalian fauna of the country (e.g. D'Elía et al. 2008, de la Sancha et al. 2009, Owen et al. 2014). This report continues and reinforces that trend, and these records from the Upper Paraná Atlantic Forest biome of eastern Paraguay also demonstrate that new and important faunal information may still be encountered, even in areas considered to be well sampled. Canindeyú Department, which includes the Reserva Natural del Bosque Mbaracayú, is the most intensively sampled department in Paraguay, with over 6,200 mammalian specimens in collections in Europe, North and South America (unpublished data). Nevertheless, this and several other recent reports illustrate that even in this heavily sampled area, the mammal fauna may yet be incompletely known, let alone the factors affecting community composition, population demographics, responses to land-use changes, and risk of zoonotic disease maintenance and transmission.

Based on this realization, we make the following recommendations: (1) advanced training of more and better field-oriented biologists, to facilitate more collect-

Figure 6. Lateral view of head, neck and forefeet (left), and ventral view of hind foot (right) of *Kannabateomys amblyonyx*, CZPLT 486.

ing and better field skills; (2) advanced training of more and better collections-oriented biologists, to facilitate better maintenance of scientific biological collections, and careful review of existing specimens; (3) better training for administrators of permit-granting entities within governments, to facilitate (rather than obstruct) scientific collection and other fieldwork; and (4) better education of administrators of both publicly and privately administered protected areas, to engender their support for scientific research in those protected areas, especially as those become the few remaining natural laboratories available.

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Authors' Contributions

All authors participated in collecting 1 or more of the specimens reported here. R. Owen drafted the manuscript and took measurements on the *D. dorsalis* and *J. pictipes* specimens. L. McMahon took measurements on the *K. amblyonyx* specimen. All authors reviewed and assisted in revising the manuscript.

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